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Weather, Climate, Web 2.0: 21st Century Students Speak Climate Science Well

Cheryl Sundberg
Ronin Institute

Teresa Kennedy, and Michael R. L. Odell
The University of Texas at Tyler

Abstract

Problem-based learning (PBL) and inquiry learning (IL) employ extensive scaffolding that results in cognitive load reduction and allows students to learn in complex domains. Hybrid teacher professional development models (PDM) using 21st century social collaboration tools embedding PBL and IL shows promise as a systemic approach for increasing teacher content knowledge of climate science and ubiquitous social media technology skills. This paper describes workshops designed to increase the climate pedagogical content knowledge (CPCK) of upper elementary and secondary teachers while providing initial and on-going scaffolding for successful implementation of PBL projects involving collaborative research on local, regional and global climate topics. Exemplars of participation by the K-12 students in the *citizen scientist* component of the "From Learning to Research" project (L2R) are described, including illustrations of recognition by local and global community members regarding students' contributions to reducing anthropomorphic impact on local ecosystems.

Climate change has become one of the most pressing issues of our time. Climate change will impact health, the economy, agriculture, water availability, disaster planning, and a variety of other areas. For much of the past decade, the politics surrounding climate change research and education has resulted in a lack of scientific understanding by many students, teachers, and citizens of the actual science behind global climate change predictions. There are many misconceptions about weather and climate such as "climate change is caused by the ozone hole", "a warm winter proves global warming", and "a cold summer disproves global warming", among others. In education, the U.S. is behind in preparing teachers and students to understand climate science and to address climate change in and outside the classroom (McCaffrey, Berbeco, & Scott, 2013). Climate is but one illustration of the need for teachers and students to understand complex interactions and to have strong systems thinking skills.

Literature Review

The *From Learning to Research* (L2R) project was designed to foster a vibrant cross-disciplinary community of learners and scholars as recommended in the NSF 21st century agenda for *Fostering Learning in the Networked World* (2008). Collaboration activities among technologists, educators, and scientists provided scaffolding for classroom teachers during the implementation phase of the project, linking participating teachers with experts in cyber learning, data visualization and analysis, social networking, and evaluation of student research projects on climate change (Comas & Barufaldi, 2011, p. 261; Helstad & Lund, 2012, p. 607; Odell, 2012; Pegg, Schmoock, & Gummer, 2010, p. 109). The L2R teachers were recruited from diverse geographic and socioeconomic communities, including inner city public schools and private schools, representing 22 U.S. states and Puerto Rico. These 75 teachers primarily taught science courses (Advanced Placement Environmental Science, Earth Science, Biology, and general science), however other subjects taught included geography, mathematics and technology (All teachers cited).

Since strategies for increasing climate change literacy can only succeed with the full engagement of the general public and important interest groups, or "stakeholders," such as businesses and local policymakers, L2R collaborative professional development activities and student research projects were planned to support the UN Convention on Climate call for governments to promote the development and implementation of educational and public awareness programs, promote public access to information and public participation, and promote training of scientific, technical and managerial personnel.

In order to function in a global, knowledge-based economy, teachers and students will need to be critical data consumers, innovative thinkers, and adept at interactive, cross-cultural communications. In a review of the literature, Shephardson and Niyogi reported prior research studies indicate teachers in the United States need professional development for addressing climate change and effective pedagogical strategies for preparing students to utilize inquiry tools necessary to make meaningful decisions based on scientific concepts (Shepardson & Niyogi, 2012).

One barrier to effective climate education is content knowledge. Few secondary and elementary teachers have a degree in the geosciences. Gonzales reported approximately 3% of science teachers in secondary school and 1 – 2% of elementary teachers have a degree in the geosciences (2010). In a report from the U.S. Department of Education, Hill and Gruber (2011) noted while science teachers generally have certification in an area of science like biology, most instructors teach other subjects. Hill and Gruber reported only 47% of students enrolled in earth science classes were taught by a teacher with a major in earth sciences (2011). On a similar note, McCaffrey, Berbeco and Scott indicated data from the National Science Teachers Association suggest that of the 150,000–180,000 science teachers in middle and high school in the United States, fewer than 16,000 teach Earth science and most lack solid background in the topic (2013).

Despite available, high-quality instructional material available either online or in other media forms to middle and high school schools, teachers often planned to use commercially prepared modules/texts as a significant source for developing science lessons according to the 2012 national survey of science and mathematics education (Banilower et al., 2013, p. 28). In the 2012 national survey, half of the middle and high school science teachers reported they "felt prepared" to teach a number of instructional tasks and of these teachers surveyed, approximately half reported they planned to use commercially prepared modules/textbooks in instruction that week, with a higher percentage of the respondent teachers in low-preforming schools planned to use traditional instructional materials like textbooks in planning lessons (Banilower et al., 2013, p. 28). However, high dependence on commercial module/textbooks can be problematic in providing teachers with support in preparing lessons on climate change. Choi, et. al (2010) surveyed middle and high school earth science textbooks, analyzing the texts for accurate, systems-thinking presentation of climate change, reporting even when climate science was included in text, often the presentation of the material was simplistic, without an exploration of the systemic nature of global climate change (p. 893 and 896).

In addition to content knowledge, teachers may have little experience using or limited resources to support student-centered pedagogy like problem-based student climate research (Rotherham & Willingham, 2009). In order for students to develop and utilize these 21st century workforce skills in the classrooms, teachers must first have experiences utilizing these same skills and access to teaching resources to support facilitation of classroom implementation of 21st Century skills. Pressured to prepare students to perform well on high stakes tests, teachers reported giving a lower priority to 21st Century skills (Goldman & Lucas, 2012). On classroom implementation of problem based learning Rotherham and Willingham (2009) wrote,

> Unfortunately, there is a widespread belief that teachers already know how to do this if only we could unleash them from today's stifling standards and accountability metrics. This notion romanticizes student-centered methods, underestimates the challenge of implementing such methods, and ignores the lack of capacity in the field today. (p. 20)

The online component L2R program provided a support scaffold mechanism for the teachers as they began classroom implementation of facilitating students' climate research projects. The teachers in the program provided real world examples of how to implement problem-based research learning projects in middle and high school classrooms.

One of the barriers identified by the teachers in the L2R program was the difficulty teaching the topic of climate change due to the *plausibility gap*, between the scientific community and the general public as termed by Lombardi, Sinatra, and Nussbaum (2012, p. 50). Lombardi, Sinatra and Nussbaum indicated the general public conceptualization of anthropomorphic-induced climate change as *implausible.* The disbelief that humans are a major component of climate change may be one factor that hinders students' more scientific conceptualization of climate change. They wrote, "as several models have predicted, plausibility may be a key component of conceptual change, particularly when the concept is one where there is a significant 'plausibility gap' between scientific and lay judgments" (Lombardi, Sinatra, & Nussbaum, 2012, p. 59).

Citizen science, while not a new conception, has evolved from primarily observation of natural phenomena like weather spotting or bird watching to innovative, high technology design now available to the general public through technological innovation. Özdemir et al., described their hope "that these micro-grants will spur novel forms of disruptive innovation and genomics translation by artisan scientists and citizen scholars alike" (2013, p. 162). The citizen science component of L2R offered resources of sample citizen science projects and a support framework as the K-12 teachers and their students in the design and execution of climate research projects and communicating the research results to the general public. The L2R professional development workshop and follow-up webinars provided strategic modeling of citizen science projects for the teachers before and during classroom implementation of the students' climate research projects as well as supporting the teachers as they assisted their students in the development of 21st Century technology and STEM skills and effective communication skills necessary as part of the future Earth Science workforce.

Theoretical Framework

The L2R model was fashioned after the technological pedagogical content knowledge framework (TPCK) articulated by Mishra and Koehler (2006). Mishra and Koehler acknowledge the TPCK framework is based on the work of Shulman, who first coined the term, *pedagogical content knowledge* (1986). Mishra and Koehler wrote,

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (2006, p. 1029)

In a similar vein, the L2R model utilized the lessons learned from the *Just in Time* professional development program implemented at the Ingenuity Center at UT-Tyler. The *Just in Time* professional development was designed to provide high school science teachers with sustained "just in time" support from high-quality professionals in utilizing technology in planning and implementing science lessons. Along with assistance in using technology to support instruction, teachers have support for content knowledge development. Initial results of the model show promise in narrowing achievement gaps among traditionally marginalized groups (Crow, 2013).

Participants of the L2R Professional Development Model (PDM) were selected from a group of middle and high school science and math educators who had training in the use of environmental protocols to study weather and climate and had three or more years of teaching experience. Communication technologies were employed in order to augment traditional on-site professional development workshops. Teachers participated in one of two week-long summer institutes held in Tyler, Texas in 2011 and in Boulder, Colorado in 2012, involving initial and follow-up training in weather/climate related environmental protocols. L2R teachers also collaborated with secondary educators across the globe and other professionals to develop and implement a climate project-based learning (CPBL) unit in their schools. The collaboration involved large group collaboration with other participants in the project and small group dialogue with teachers and their students completing the CPBL.

Using 21st century tools for social collaboration, teachers and their mentors used the following: videoconferencing tools such as Adobe Connect, website with threaded discussion board, webinars, YouTube, Skype, email and cell phones. Throughout the follow-up online PDM, teachers and mentors participated in webinars hosted by weather and climate professionals from the National Weather service, media, and professors from across the U.S. and internationally. Teachers hosted webinars describing the progress of their projects with the students, including sample data analysis prepared by the secondary students and photographs of the students taking environmental measurements as described in the GLOBE (Global Learning and Observations to Benefit the Environment) Teachers Guide (GLOBE, 2005).

A highlight of the implementation of the citizen science portion of L2R was the positive impact in the ability of the K-12 students to serve as citizen scientists, writing and presenting the impact of their research of the impact of climate change on local ecosystems. Glenn (2007) provided a framework to describe effective citizen science projects: rigorous data collection, pooling and verifying cumulative results, vetting amateurs, and expert-amateur interaction. Scaffolding project based learning and inquiry learning methodologies addresses enhance content knowledge, epistemic practices, and soft skills such as collaboration and self-directed learning (Hmelo-Silver, Duncan & Chinn, 2007). In a similar fashion, the model for the citizen science portion of L2R could be visualized by the following graphic.

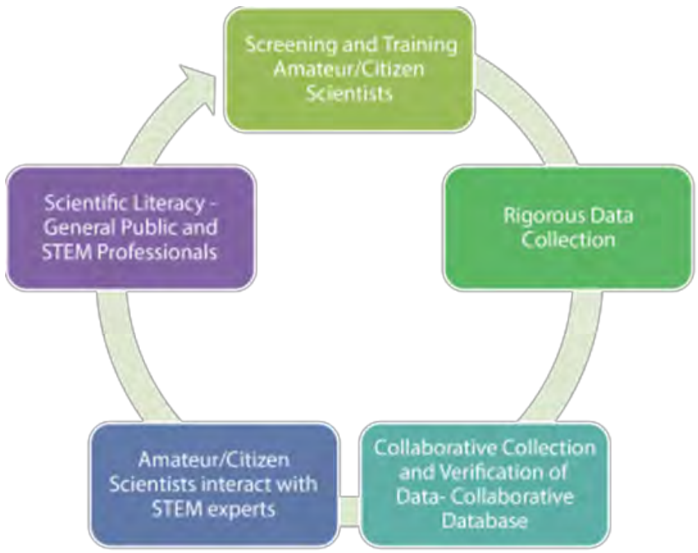

Figure 1. Graphic Illustrating Citizen Science Portion of L2R

There are many definitions of citizen scientist (OpenScience.org, 2011). For the purposes of this research, the definition by *Scientific American* was used to frame the study. *Scientific American* defined citizen scientists as non-specialists involved in particular scientific research projects:

> Research often involves teams of scientists collaborating across continents. Now, using the power of the Internet, non-specialists are participating, too. Citizen Science falls into many categories. A pioneering project was SETI@Home, which has harnessed the idle computing time of millions of participants in the search for extraterrestrial life. Citizen scientists also act as volunteer classifiers of heavenly objects, such as in Galaxy Zoo. They make observations of the natural world, as in The Great Sunflower Project. And they even solve puzzles to design proteins, such as FoldIt. (*Scientific American*, 2013)

Research Methodology

Overview and Guiding Research Questions

The descriptive study of a convenient sample of digital artifacts generated during a hybrid teacher professional development program centered on climate education is a brief portraiture of how teachers and their students describe concepts of weather and climate after participating in a climate research project or projects facilitated by their teachers. At the end of a week-long face-to-face professional development workshop, participating teachers outlined possible research projects for their students linking local weather/climate data and events to global climate patterns like global warming. Through initial examination of the digital artifacts, a brief glimpse of how the teachers and their students could articulate research methodologies in measuring weather phenomena and accessing secondary sources of weather and climate data to support research conclusions.

The guiding research questions provided a lens to frame the brief, descriptive portraitures:

- What promise does the L2R Model CPCK PD hold for supporting effective communication by teachers and students as future citizen scientists using Web 2.0 tools?
- How does the extended PD from the L2R Model CPCK impact teacher and student narratives/skills in terms of professional/citizen scientists? Are the students able to articulate local earth science events using current scientific terminology, well-written prose, powerful graphical images, and eye-opening photographs of local events with ubiquitous tools like a cell phone? Are the students able to publish their citizen science news reports to suitable news venues?

Research Method

Descriptive research methodology was used to describe the L2R project and categorize webinar snips based on evidence the teachers' webinar presentations illustrated successful classroom implementation of climate change PBL as well as the use of technology to support instruction and social collaboration for continued professional development. After initial analyses, coding of the webinar snips with subsequent categorizing into themes as described by Saldaña (2011) was completed as part of emerging grounded theory in a model professional development in CPCK.

Sample

The research was a descriptive study of a convenient sample of digital artifacts generated during a hybrid teacher professional development program. The weeklong workshop on climate education was subsequently followed by continuing online professional development. The digital artifacts used in the study were a convenient sample of digital products produced by the teachers during the weeklong workshop and the follow-up online webinars. The teachers (approximately 75, in two cadres) were selected from applicants across the nation, most of whom had some experience collecting weather data using weather stations or environmental data like water quality data.

Workshop Description

The week-long, face-to-face/virtual summer workshops offered teachers hands-on/minds-on field experiences in collecting weather data using instruments like pH meters, thermometers, cloud charts, and anemometers. Instruction in the use of Web 2.0 communication technologies included real-time audio/video conferencing tools, accessing digital collections of weather/climate data like ships' logs, speakers from meteorologists, biologists, and other professionals, and writing drafts of research design were provided to the teachers to support subsequent classroom implementation.

Follow-up Webinars

Continued instruction on weather/climate concepts and STEM careers in climate research was provided by career speakers from scientists and professional meteorologists as a regular part of the follow-up professional development webinars. Each group of teachers involved in the program provided progress reports of classroom implementation of the local weather/climate research projects. Students presented the results of their climate research projects at the virtual conferences in May.

Data Sources

The digital artifacts examined in the research included snips of online YouTube videos of teacher presentations during follow-up webinars, student presentations during follow-up webinars and virtual conference, and local newspaper articles which highlighted the student climate research projects. Snips from the webinar presentations and students' presentations at the virtual conferences in May were examined for evidence of students' ability to articulate local earth science events using current scientific terminology, well-written prose, and graphical images.

> Every 'representational' process involves a translation or conversion of some kind – a process of inscription, transcription and/or fabrication whereby the initial source (phenomenon, concept) is captured, transformed, or even (re)created through a chain of decisions that involves several actors (scientists, artists, technicians), technological devices and normative settings. This complex process of meaning-making has an important impact on what and how it can be known, on what is revealed or obscured, and on what is included or excluded. (Pauwels, 2008, p. 151)

Snips from the presentations were selected as representative evidence of the students' ability to articulate ideas and concepts of climate research. Using Pauwels' (2008, p. 158) description of a conceptual framework for assessing and creating visual representations for scientific purposes, the researchers used the visuals and dialogue in the YouTube videos and presentations generated by the students and teachers as one method to view gains in conceptualization of climate research.

Data Analyses

The webinar snips were coded based on the goals of L2R (see below), (Saldaña, 2011, p. 104). The *coding* (Saldaña, 2011, p. 104) of the webinar snips were then clustered into *themes* (Saldaña, 2011, p. 116) as part of the preliminary probing of the artifacts for subsequent analyses in the emerging grounded of CPCK.

A summary of the L2R project goals, which were used in the initial coding:

1) Produce research findings on teacher and student use of online GIS, data analysis, modeling and social collaboration tools (technology knowledge),
2) Develop, implement and evaluate the GLOBE Student Research Collaboratory's impact on motivating and preparing middle and high school students for STEM careers.
3) Equip teachers with resources and strategies to ensure their students know about and are prepared to pursue STEM careers in disciplines like climatology and meteorology, land use planning, and ecosystem modeling (National Science Foundation under Grant No.0929725).

Pauwels (2012) noted the Internet is "a highly hybrid multi-authored cultural meeting place, connecting off-line and online practices of different cultures in transition" (p. 260). In a similar vein, analyzing presentations prepared by the L2R teachers was difficult because the evidence included a variety of media: digital presentations, graphs, charts, and verbal interactions through webinars. As Pauwels (2012) reported in a discussion of cultural website analysis, any type of media research, may take a snapshot approach (focusing on a static slide of a dynamic medium at a certain point in time), p. 251. The research in this study used the method described by Pauwels where a static slide of a dynamic medium at a certain point in time was analyzed; the research investigated web clips of the webinars presented by the teachers as a part of the ongoing follow-up professional development (2012.) Adapting the initial phase of Pauwels' Multimodal Framework for Analyzing Websites, the research utilized what Pauwels described as the immediately manifest features as a way to begin analysis of the webinars (2010, pp. 251-252). The analysis categorized a convenient sample of photographic clips drawn from the archived webinars and subsequent comparision of the information on the webinar clips to guidelines from current curricular improvement projects on climate change and basic skills for all students (21st Century Skills, Next Generation Science Standards, and Common Core Standards). Table 1of exemplar webinar snips illustrates the initial analysis of evidence from the webinars of gains in teacher climate content pedagogical knowledge and student climate content knowledge. While the analyses in this research did not focus on website design, Pauwels' Framework offers a method for beginning to customize and codify the information selected by the teachers to present at the webinars on a more in-depth level.

Webinar Codification Framework, Initial First Impressions of Salient Topics

Table 1. Examination of Webinar Snips for Teacher CPCK and/or Students' CCK using 21st Century Skills

21st Century	Criteria for Selecting Representative Photograph	Selected Photograph as Evidence	Teacher CPCK	Student CPCK
• **Global Awareness**	Photograph illustrates collaboration among diverse cultures. In the L2R PD context, teachers collaborated among peers in their building and other teachers from different states/biomes.	Figures 10, 11, and 12, School 4 – teacher prepared graphic used in instruction	✔	
		Figure 17, School 6 - teacher prepared graphic used in instruction	✔	
		Figures 19 and 20, Schools 7 and 8- students from school in far north USA collaborate with students in tropical USA climate		✔
		Figure 21, School 7 – sample student data		✔
• **Environmental Literacy**	Photograph illustrates student collecting/analyzing field data collection and/or historic document data/analysis on environmental issues	Figure 5, School 1 – student sample notebook, research data	✔	✔
		Figures 6 and 7, School 2 – students collect indicator aquatic species data		✔
		Figures 8 and 9, Schools 3A and 3B – teacher/student prepared graphics summarizing data analysis documents	✔	✔

		Figures 10, 11, and 12, School 4- teacher prepared document used in instruction	✔	
		Figure 14, School 5 – students collect weather station data		✔
		Figures 16, 17 and 18, School 6 – students collect data		✔
		Figures 19 and 20, Schools 7 and 8 – students collect data		✔
		Figure 21, School 7 – sample student data		✔
• **Communication and Collaboration**	Photograph illustrates students working in teams to collect/analyze data	Figure 5, School 1 – sample student data presented by team member		✔
		Figures 6 and 7 School 2 – student collected indicator species, teams of students seined for indicator		✔
		Figures 8 and 9, Schools 3A and 3B – student/teacher prepared graphic illustrating summary of analysis of historic data		✔
		Figures 16, 17, and 18, School 6 – students collect data in field on impact of global warming on migration of Canada geese		✔

		Figures 19 and 20, Schools 7 and 8 – students from schools in Taiga/temperature rain forest collaborate with students in tropical rainforest of USA on data collection of bud burst, green up/green down, biomes		✔
		Figure 23, School 7 – students collect and record field		✔
• **Critical Thinking and Problem Solving**	Photograph illustrates students collecting field data for subsequent analysis and evaluation of evaluate evidence, arguments, claims and beliefs to support/refute hypotheses	Figure 6, School 2 – students collect indicator species in aquatic ecosystem, compare historic and current data to support refute hypotheses		✔
		Figures 8 and 9, Schools 3A and 3B – students and their teacher prepare graphics illustrating summary of historic document		✔
		Figures 16, 17, and 18, School 6 – students collect current water		✔
		Figures 19 and 20, Schools 7 and 8 – students from schools in Taiga/temperate rain forest and tropical rainforest collect/share green up/green down		✔
		Figure 21, School 7 – student data sample		✔
• **Social and Cross-cutting Skills**	Photograph illustrates students working effectively with peers/mentors from diverse cultural backgrounds	Figures 19 and 20, Schools 7 and 8 – students from schools in Taiga/temperate rain forest and tropical rainforest collect/share green up/green down		✔

Table 2. Examination of Webinar Snips for Earth Science Content – Teacher CPCK and/or Students' CCK using Next Generation Science Standards

Next Generation Science Standards – Earth Science Content	Criteria for Selecting Representative Photograph	Selected Photograph as Evidence	Teacher CPCK	Student CPCK
MS-ESS3-3: Monitoring and Minimizing Human Impact on the Environment	• Photograph illustrates students collecting data in field • Photograph illustrates teacher-prepared materials used for instruction in global climate change	Figures 2, 3, and 4 School 1 – students collect field data		✔
		Figures 6 and 7, School 2 – students collect indicator species data in aquatic ecosystem		✔
		Figures 8 and 9, School 3A and 3B – student and teacher prepared graphic illustrating summary of analysis of historic data	✔	✔
		Figure 10, School 4 – teacher prepared graphic used to illustrate extreme weather across USA	✔	
		Figures 14 and 15, School 5 and Figures 16, 17, and 18, School 6 – students collect field data		✔
		Figures 19 and 20, Schools 7 and 8 – students collect field data and collaborate with peers in different biomes (Taiga/temperate rainforest, tropical rainforest)		✔
		Figure 21, School 7; and Figure 22, School 7 – sample student field data		✔
MS-ESS3-5: Ask Questions about Causal Factors of Increased Global Temperatures in the past 125 years	• Photograph illustrates students collecting data • Photograph illustrates teacher or student generated	Figure 5, School 1. Figure 6, School 2, and Figure 21, School 7– sample student data		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher generated graphic	✔	✔

	graphics used to summarize data/data analysis	used to summarize data analysis		
		Figures 10, 11, and 12 School 4 – teacher generated graphics used to illustrate effects of increased average global temperatures on extreme weather events	✔	
		Figure 14 and 15, School 5; Figures 16, 17, and 18, School 6 and Figures 19 and 20, Schools 7 and 8- students collect field data		✔
ESS3.D: Global Climate Change: Concepts of weather, climate, climate change	• Photograph illustrates students collecting data • Photograph illustrates teacher or student generated graphic used to illustrate impact of additional energy to weather systems • Photograph illustrates teacher or student generated graphic used to illustrate impact of increased average global temperature to extreme weather	Figures 1, 2, 3 and 4, School 1; Figure 7, School 2; Figures 14 and 15, School 5; Figures 16, 17, and 18, School 6; Figures 19 and 20, Schools 7 and 8– student collect field data		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher generated graphic summarizing analysis historic data	✔	✔
		Figures 10, 11, 12, and 13, School 4 – teacher prepared graphic illustrating local extreme weather	✔	
		Figure 21, School 7; Figure 22, School 11 – sample student data sheets		✔

Table 3. Examination of Webinar Snips for Science and Engineering Practices – Teacher CPCK and/or Students' CCK using Next Generation Science Standards

Next Generation Science Standards – Cross-cutting Concepts	**Criteria for Selecting Representative Photograph**	**Selected Photograph as Evidence**	**Teacher CPCK**	**Student CPCK**
MS-ESS3-2, Patterns: Graphs, charts, and images can be used to identify patterns in data.	Photograph illustrates student or teacher prepared graphics (graphs, charts, and images used to identify patterns in the data.	Figure 5, School 1; Figure 17, School 6; Figure 21, School 7;– sample student field data in chart		✔
		Figure 6, School 2 – sample student field photograph of indicator aquatic species		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher graphic illustrating summary historical data	✔	✔
		Figures 10, 11, 12, and 13, School 4 – teacher prepared graphics illustrating local, regional, and national extreme weather events	✔	
MS-ESS3-3, Cause and Effect: Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	Photograph illustrates possible indicators for impact of increased average global warming, i.e., change in population indicator species or increased extreme weather events.	Figures 1, 2, 3, and 4 School 1 – students collect field data		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrating increased asthma compared to increased levels of ozone, component of air pollution	✔	✔

		Figures 10, 11, 12, and 13, School 4 – teacher prepared graphic illustrating increased extreme weather fueled by increased average global temperatures	✔	
MS-ESS3-1, MS-ESS2-4, Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Photograph graphic elements designed by students or teachers or used by teachers to illustrate change in weather or species due to increased average global temperature : increased extreme weather events, change in migration habits of animals like Canada geese, change in population of various species, etc.	Figure 6, School 2 – student sample of population of species in aquatic ecosystem		✔
		Figure 17, School 6 – student sample of water quality data and students collecting data, investigation of impact of non-migrating Canada geese on local pond		✔
		Figure 21, School 4 – student sample green up/ green down data		✔
		Figures 8 and 9, Schools 3A and 3B – graphic prepared by students and teachers to illustrate increased asthma as a result of increased ozone levels from anthropomorphic activity	✔	✔
		Figure 10, 11, 12, and 13, School 4 – teacher prepared graphics used to teach increased local extreme weather events, comparison of local extreme weather to regional/national extreme weather events	✔	

MS-ESS3-5, Stability and Change: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.	• Photograph illustrates extreme weather fueled by warmer air temperatures. • Photograph illustrates impact of higher average global temperatures on local flora/fauna.	Figure 6, School 2 – student collection fauna, examining impact of warmer temperatures on aquatic life		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrates impact of increased temperature on ozone pollution, resulting in increased asthma attacks.	✔	✔
		Figures 10, 11, 12, 12, School 4 – teacher prepared graphics illustrating recent local extreme weather events due to higher than average global temperatures	✔	
		Figures 17 and 18, School 6 – student data on water quality impacted by non-migrating Canada geese		✔
		Figure 21, School 4 – student data on green up/green down, impact on bud burst dates due to increased average global temperatures		✔

Table 4. Examination of Webinar Snips for Literacy – Teacher CPCK and/or Students' CCK using Common Core, Literacy

Next Generation Science Standards – Cross-cutting Concepts	**Criteria for Selecting Representative Photograph**	**Selected Photograph as Evidence**	**Teacher CPCK**	**Student CPCK**
ELA/Literacy: RST.6-8.1 – Cite specific textual evidence to support analysis of science and technical texts.	Photograph illustrates use and analysis of text material to prepare graphics	Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrating summary of current and historic data on number of asthma patients and ozone monitoring stations over time.	✔	✔
ELA/Literacy: RST.6-8.7 – Integrate quantitative/technical information in text with visuals (graphs, charts, flowcharts)	Photograph integrates text with graphic visuals (tables, graphs, charts, etc.)	Figure 5, School 1 and Figure 21, School 4; – student data tables and graphs		✔
		Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic, illustrating summaries of historic data on asthma patients and ozone levels	✔	✔
		Figures 10, 11, 12, and 13 School 4 – teacher prepared visuals used to illustrate local, regional, and national extreme weather events	✔	
ELA/Literacy: WHST. 6-8.1 – Write arguments focused on a specific discipline	Photograph illustrates student produced product focused on supporting arguments for hypotheses using evidence	Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrating increased asthma patients with rise in ozone levels	✔	✔

WHST.6-8.7 - Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration	Photograph illustrates some aspect of the research process: data collection, organizing data in tables, preparing summary graphics, etc.	All figures	✔	✔
WHST.6-8.8 - Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources	Photograph illustrates students analyzing data from multiple sources and producing summary visuals	Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrating increased asthma patients with rise in ozone levels	✔	✔
WHST.6-8.9 - Draw evidence from informational texts to support analysis, reflection, and research	Photograph illustrates students analyzing data from historical data to support field data	Figures 8 and 9, Schools 3A and 3B – student and teacher prepared graphic illustrating increased asthma patients with rise in ozone levels	✔	✔

Table 5. Examination of Webinar Snips for Literacy – Teacher CPCK and/or Students' CCK using Common Core, Mathematics

MP.2 - Reason abstractly and quantitatively	Photograph illustrates collection, organization and analysis of data	Figure 5, School 1; Figure 17, School 6; Figure 21, School 7 – student data sheets		✔

Results

In the L2R project, middle and high school students participated in projects on a variety of environmental topics such as phenology, monitoring trees for budburst and green-up. In the process of completing varied citizen science activities, students gained valuable experience in communicating science with their peers and the general public. Personal narratives motivate students as Goldenberg noted:

> Students enjoyed learning science through narratives; anecdotes about scientists show that theories are not only abstract ideas but are created by people. They also demonstrate how discoveries build on one another and illustrate that scientists are not just old, white-haired men in lab coats. (2011, p. 55)

For example, students at one L2R school presented their paper *Phenology and Climate Project* at an international conference in New Delhi, India (Dassing, 2012). According to one student, "It's been really interesting getting to be a part of it … it's neat to think that students in a small town of about 1,300 people get to interact with people from around the world because of a research project" (Student B, School1) (Guevara, 2012).

In addition to typical scientific paper presentations, students involved in the L2R project had opportunity to gain valuable experience as citizen scientists. Through the lens of a scientist, students collected weather data using specified protocols and instruments and then accessed Web 2.0 technology (word-processing, spreadsheets, presentation software, and online, real-time or asynchronous communication tools) to communicate with peers and mentors like meteorologists. After collecting data using specified instruments, conducting research from Internet resources, and communicating with professionals like local Earth scientists, K-12 students prepared media rich presentations subsequently shared with peers and mentors using Web 2.0 communication tools.

Students at School 1 prepared and uploaded a YouTube Video describing their bud burst research. Students A, B, and C described the protocols used to conduct the research, illustrated data collection notebooks, and outlined preliminary results/conclusions (School 1, Bud Burst Movie, 2012).

Figure 2. Student A explains instrument box. (School 1, Bud Burst Movie, 2012).

Figure 3. Student B illustrates rain gauge. (School 1, Bud Burst Movie, 2012).

Figure 4. Students C and A show specimen collection. (School 1, Bud Burst Movie, 2012).

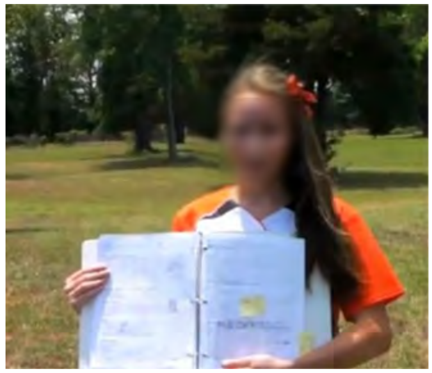

Figure 5. Student B explains data collection notebook. (School 1, Bud Burst Movie, 2012).

In a YouTube video, students from School 2, articulated research in the health of a stream, measuring pH, water flow rate, water temperature and flora/fauna of the stream. Students used high tech research tools during the research like ArcGIS, GPS, and remote sensing to examine and analyze the health of the stream.

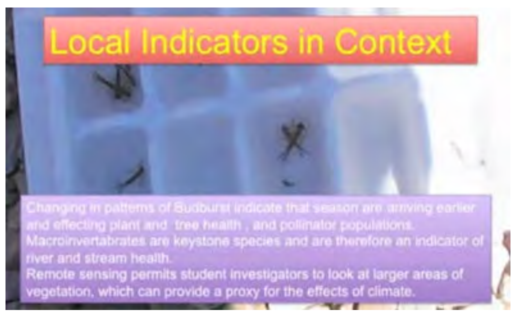

Figure 6. Students record local indicator species (School 2, Macro Study Movie, 2012).

Figure 7. Seining stream for indicator species (School 2, Macro Study Movie, 2012).

Students at two schools in North Carolina examined a possible positive correlation with an increase in asthma cases and urban sprawl (Schools 3A and B. Webinar, 2013). Accessing historical data from local health departments, archived and real time readings of ozone levels from government sources, along with student collected data, students learned to use ArcGIS to prepare maps suitable to support their conclusions. With assistance from a local university geologist, students at Schools 3A and 3B prepared maps like the following:

Figure 8. Sample ArcGis map ozone air quality sites (Schools 3A and 3B. Webinar, 2013).

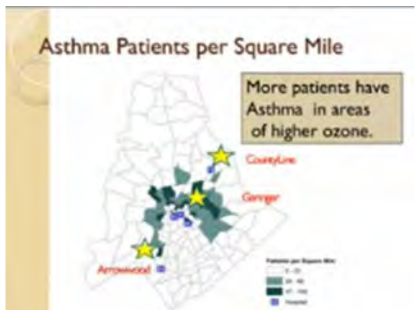

Figure 9. ArcGis asthma patients per square mile (Schools 3A and 3B. Webinar, 2013).

Learning to use ArcGIS as a means of communicating scientific data to the general public, the students at School 3B were excited to participate in the North Carolina's Regional ArcGIS Day at a local university. According to Comas and Barufaldi (2011, p. 261), effective teacher professional development is evidenced when teachers and their students are excited to go beyond the parameters of the original project (Schools 3A and 3B. Webinar, 2013).

The positive impacts of the L2R project were not limited to the teachers who participated in the professional development. Three teachers in North Carolina, School 4, reported their entire school used the L2R effective instructional framework as a guide for school-wide improvement, an indicator of success of the L2R CPCK (School 4. Webinar, 2012; Comas & Barufaldi, 2011, p. 261).

Along with the climate research project designed for the L2R project, teachers involved in the CPCK often explored the use of Web 2.0 tools to supplement other facets of science instruction, in particular, placing Earth science concepts in local contexts (Barlow, 2008). The contextualization of Earth science constructs on a local level were intrinsically motivating for the students as they wanted to share their personal narratives of extreme weather events happening over the summer in West Virginia (School 4, Webinar, 2012).

As noted by Larkin, King and Kidman, indigenous stories and integration of technology (*Google Earth*) provide motivation for students to learn about landforms and in addition positively impacted students' conceptualization of concept. The teacher reported, "…it was satisfying to connect indigenous perspectives with science content. The students were engaged throughout the task and the level of work submitted by the students matched, or bettered, the students' usual grades" (Larkin, King, & Kidman, 2012, p. 5).

Larkin et al. indicated the use of social communication technologies piqued students' interest in learning geology concepts and posited,

> the connections the students made between the indigenous story and science concepts were encouraging in this unit of work…Further connections could be explored through inviting indigenous members to speak to students or connecting with remote schools by utilizing Web 2.0 technologies such as blogs or Skype. This may afford students opportunities to discuss their science reports with elders and colleagues who are familiar with the area and provide deeper insights into the geological connections and dreaming stories. (2012, p. 5)

Using Web 2.0 resources, two teachers from West Virginia shared how excited their students were to share stories about some of the significant weather events over the summer. First, Teacher 1, School 4, indicated how she used a visual summary of an extreme weather local event as a beginning for a class discussion and introduction of science concepts associated with wind storms like the derecho.

Figure 10. Map illustrates significant weather events summer 2012 (School 4, Webinar, 2012).

Figure 11. Online weather radar map shows derecho summer 2012 (School 4, Webinar, 2012).

The archived radar imagery allowed the students to view the extent of the 700 mile long June 29, 2012 Midwest/Ohio Valley Derecho. Students were excited to share their personal experiences of the wind storm with winds reaching a Class 1 hurricane force in some places (School 4, Webinar, 2012).

In addition to the windstorm, using archived imagery of the summer heat wave was a technique used by Teacher 1, School 4 to explain possible reasons it was so hot in West Virginia last year.

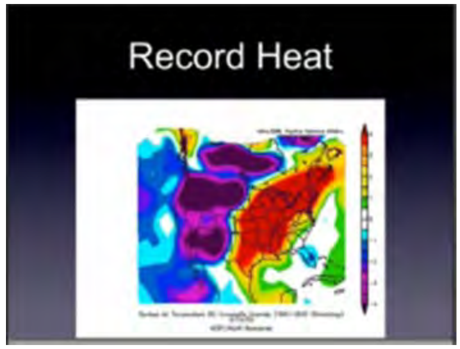

Figure 12. Archived imagery used to explain summer heat wave (School 4, Webinar, 2012).

Students from School 4 in WV also experienced localized flooding during the past summer. Teacher 1, School 4 used personal photographs to explain local significant weather.

Figure 13. Local flooding summer 2012 (School 4, Webinar, 2012).

Teachers 2 and 3, School 4 shared personal stories of Earth science projects not part of the L2R CPCK. For example, a Teacher 3 from West Virginia shared the installation of a rain garden on campus the previous spring and was pleased to report the students wanted to view the rain garden after several large storms struck the local region and look for evidence rain garden was functioning properly to reduce excess rain water runoff into the local watershed (School 4, Webinar, 2012).

Not only did the teachers in the L2R program articulate the use of high tech instruments to measure weather data in the webinars, their students discussed how data was collected in YouTube videos. Middle school students from School 5 described the various tools used in the research for their summary of research presented at the L2R virtual conference in May 2012. Weather station instruments like thermometers and barometers, along with plant color charts were used by the middle school students at School 5 in their Green Up/Green Down research project (School 5, Webinar, 2012).

Figure 14. Student demonstrates barometer (School 5, Webinar, 2012).

Figure 15. Instrument box (School 5, Webinar, 2012).

Connecting science phenomena to local events sparks interest in learning. Teachers at School 6 (southern state) described the negative impact on the local ecosystem when Canada geese are now year-round residents at a local lake (fouling of the lake, possible spread of disease from geese waste, and aggressiveness of the fowl). Their students wanted to know why there were so many geese at a local lake. The students conducted research from historical accounts and collected daily air temperature data to study how the elevated average daily air temperatures had changed the migration patterns of animals like Canada geese (School 6, Webinar, 2012).

Figure 16. Sharing data - impact of Canada geese on local lake (School 6, Webinar, 2012).

In addition to the climate research on global warming, the students examined how global warming impacted the health of the local lake. Geese elimination products change the nitrate levels in the lake, fertilizing aquatic plants like duckweed and escalating the possibility for fish kills as the dissolved oxygen levels decrease with soaring plant growth. Below, Student E, School 6, used a wet lab test for nitrates to determine water quality in the lake inundated by resident Canada geese (School 6, Webinar, 2012).

Figure 17. Water quality testing, impact of Canada geese on local lake (School 6, Webinar, 2012).

Figure 18. Collecting data on impact of Canada geese on local lake (School 6, Webinar, 2012).

A central focus of the L2R research involved collaborative research among participants and scientists. Partnerships among schools evolved as teachers outlined possible driving questions for student research designed to examine local events/phenomena related to climate research. For example, Students from Schools 7 and 8 compared bud burst dates, examining the impact of latitude and altitude on plants. School 7 is located in an alpine, tropical rain forest and School 8 is located in a subtropical rain forest. Using online communication tools both synchronous and asynchronously, students were able to compare bud burst dates with peers at the school in the L2R project conducting similar research, how global warming has impacted bud burst dates. In addition to the climate research, the students at Schools 7 and 8 could interact with each other, comparing and contrasting the local climes.

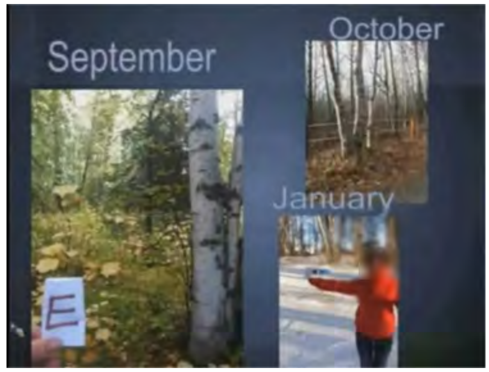

Figure 19. Seasonal photographs (School 7, Webinar, 2012).

Figure 20. Students measure canopy cover (School 8, Webinar, 2012).

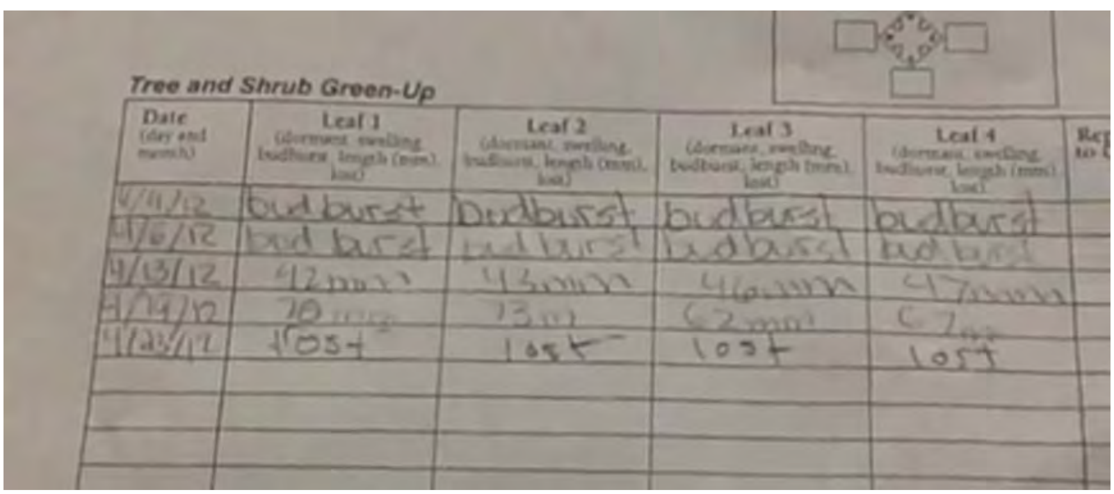

Figure 21. Sample student data sheet Budburst (School 7, Webinar, 2012).

School 11 investigated a possible correlation between urban heat island effect and the production of aerosols. Using an Excel spreadsheet prepared by a local university professor of earth science, middle schools students entered aerosol data collected at rural and urban locations into a spreadsheet, expecting a strong correlation between surface temperature and the presence of aerosols. At the time of the webinar, the final analysis of the students' data had not been completed (School 11, 2013). In addition to collaboration with the local scientist, students participating in the GLOBE Aerosol Research Campaign prepared a final project, an argumentative paper with a digital story component, a critical component of the Common Core State Standards (2010).

Figure 22. Students Use Excel Spreadsheet to Analyze Data

During temperate portions of the year, the canopy cover is similar for the research sites of Schools 6 and 7. The students at Schools 6 and 7 were able to view the weather and climate of rain forests near the equator with those in an alpine ecosystem. The students were able to hear contemporaries describe how the forests in the subtropical rain forest had a canopy cover year round while students in the alpine region were able to illustrate how the canopy is practically nonexistent during the colder parts of the alpine rain forest by connecting via Adobe Connect. In addition, the students at both schools could examine the types of plants found in the two niche climes by comparing data with their partner school; plants found in alpine rain forests are different from those in subtropical rain forests. Trees in an alpine rain forest are typically conifers while deciduous trees blanket subtropical rain forests.

Student leadership emerged as an important asset of the L2R program. Often, high school students assisted younger students in data collection on field trips to the research site. School 6 high school students helped third graders collect data on phenology (School 7, Webinar, 2012).

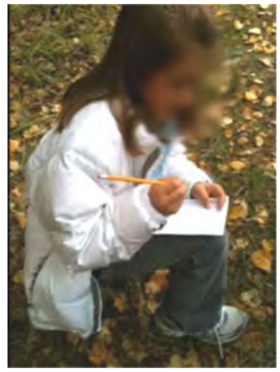

Figure 23. Student collects data (School 7, Webinar, 2012).

Figure 24. High school students assist younger students collect data (School 7, Webinar, 2012).

Other sites also described how high school students mentored younger students in collecting and analyzing data. In a newspaper interview of high school students of School 1, Student A reported the mentoring of younger students collecting data for climate research.

Participants in the L2R PD collaboratively planned strategies suitable for facilitating K-12 student climate research. School 9 illustrated a typical opening activity or bell ringer used at the beginning of the lesson:

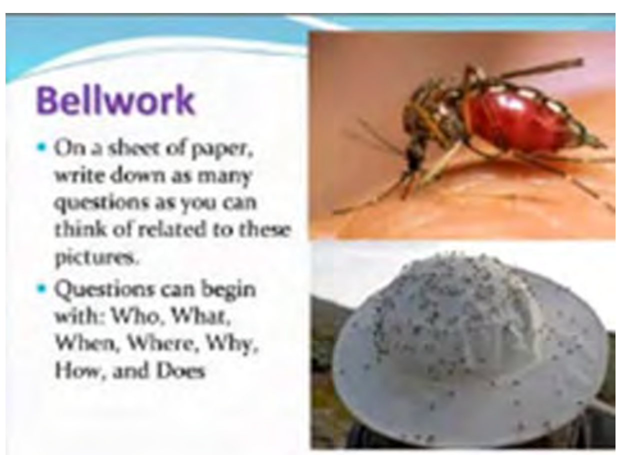

Figure 25. Bellringer activity (School 9, Webinar, 2012).

The teachers utilized local experts to serve as mentors for the K-12 students as the climate research projects started. Climatologists along with biologists and other scientists provided mentoring during the research project. School 8 teachers reported the local experts they leveraged during the research process.

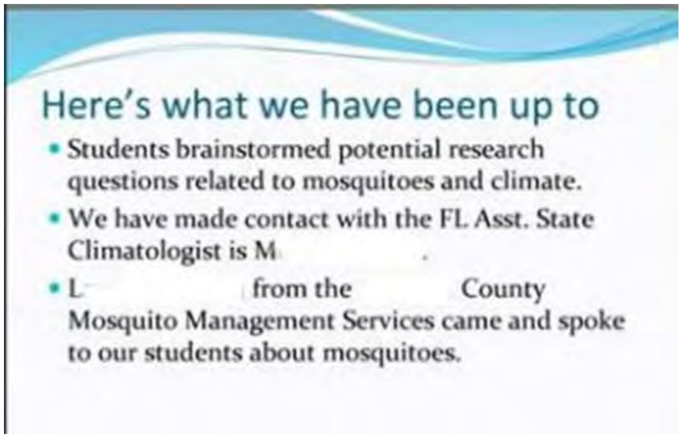

Figure 26. School research project progress report (School 9, Webinar, 2012).

Implications

The primary research question for L2R centered on the use of communication technology tools to provide follow-up, continuous professional development opportunities for teachers on facilitating K-12 student climate research. As evidenced from the webinars and other artifacts of the L2R research project, the teachers did collaboratively plan and execute lessons facilitating K-12 student climate research. During the year, the students were able to collaborate with contemporaries at other schools, comparing and contrasting data collection/analysis and preliminary conclusions, as illustrated by online webinars and YouTube videos.

An increase in content knowledge of climate change was evidenced from the various student and teacher presentations in the webinars and online virtual conference. A survey of the dialogue and graphic representations provided by the students and teachers, offer a glimpse of the increased knowledge of global climate change and the impact on local ecosystems. Unlike typical pen and paper assessments, the L2R project leveraged Web 2.0 tools as a means for determining higher ordered thinking skills, such as the preparation of graphs, tables and other graphical representation, summarizing data, synthesis of data trends, and oral/written communication of research.

The articulate presentations by secondary and upper elementary students and their teachers substantiate the L2R CPCK professional development institute and online follow-up sessions as a model for continuous professional development on weather and climate concepts and student climate research. Unlike aggregated and disaggregated quantitative data, analysis of the online artifacts, including webinars and YouTube videos, allows researchers to view how K-12 students can synthesize content information, prepare research projects using typical scientific methodologies and protocols, and prepare suitable reports of trends in the data with implications for future research. The sample lesson activities and support for teachers as they planned lessons designed to facilitate students' research in climate change, are congruent with current reform, e.g., 21st Century Skills, cross-cutting STEM concepts/processes, and problem-based learning.

Next Steps and Limitations of the Study

The descriptive research of this study was designed to provide a brief portraiture of conceptual gains in understanding weather, climate and climate research. Further research should examine more fully the students' conceptualizations of climate research, including a comparison study with students whose teachers did not participate in the professional development program. The use of Pauwels' (2008, p. 151) conceptual framework for visual competence might serve as a referent for more intense research in the students' text/visual dialogue as a means of measuring gains in conceptual understanding of climate research. This study was descriptive in nature and results cannot be generalized. In addition, the L2R project was limited in scope to students' climate change research and further study should consider the utility of the model to facilitate continuous professional development on other content areas.

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